state debt policy and state bond market behavior

Vitaly Barinov
Anatoly Pervozvansky
Tatyana Pervozvanskaya

working paper series
No 99/05
april 1999

This working paper is issued under the program area *Macro & Finance*
Any opinions expressed here are those of the authors and not those of the Economic Education and Research Consortium. Research dissemination by the EERC may include views on policy, but the EERC itself takes no institutional policy positions.

This project was supported by Russia Program of Economic Education and Research Consortium managed by the Eurasia Foundation (Grant N# 97-0231).
The authors wish to thank Professor Giovanni Urga and Professor Victor Polterovich for many helpful comments.
We are indebted to Olga Kozlova for her assistance.

CONTENTS

NON-TECHNICAL SUMMARY

The history of the government bond (GKO) market in Russia is short and turbulent. Formally modeled in 1993 after the US T-Bill market, it exhibited a dramatically different behavior from the very beginning. Instead of providing a low-return, riskless anchor to financial markets GKOs became highly speculative securities. The main goal of our research project was to study investment processes in the GKO market in conjunction with government debt policy and developments in the foreign exchange market. Debt policy was initially quite rudimentary: during 1993–4 it served the purpose of attracting funds from the foreign exchange market to the GKO market by offering exceptionally high yields. Later (1995–6), the debt was used as a non-inflationary tool to finance the budget deficit. In the late 1996 through early 1997 attempts to lower the yields were confronted with resistance of commercial banks, which began to divert funds from the GKO market, first making huge investments in stocks and later using funds to buy foreign exchange, which was becoming progressively scarce with the rapid decline of world energy prices. The international financial crisis led to foreign capital flight and provoked a further fall in prices. Early in 1998 service payments on the Russian government debt exceeded the revenue from new issues. As a result, the GKO market collapsed in the middle of the year. GKO market behavior was thus determined by internal and external economic factors (budget deficit, world oil and financial crisis), as well as the debt issue policy and the behavior of large investors.

For each of these stages, the authors have identified the main factors affecting GKO yields. During the first stage, the predominant factor was competitive pressures of the foreign exchange market. Subsequently, when the GKO market became the dominant segment of the domestic financial system, absorbing most of its investment potential, the yields were mostly influenced by the demands of deficit finance. At that stage, domestic investors were solely interested in the relative profitability of different issues of the bonds. During the third stage GKO yields began to feel pressure not only from the foreign exchange market but also from the stock market, and were strongly affected by the lending policy of the Central Bank and international market conditions.

The main research objective of our project is the optimal forecasting of short-run fluctuations and the analysis of the use of these forecasts in speculative decision-making. The erratic short-run behavior of the yields is the result of interactions of many agents acting in the main competitively and independently. Meaningful analysis of those processes can be undertaken only on the basis of modern investment theory, which is the extension and modification of classical portfolio theory. The core of the theory is the assumption that rates of return are realizations of stochastic processes, which can be forecast on the basis of all information available to the investor – the trading history and other factors.

The authors proposed evolutionary series as a tool to analyze short-term GKO returns as realizations of random sequences, and statistically characterized their salient properties (non-stationarity, non-normality, autocorrelation). They studied the forecasting accuracy of various statistical procedures and demonstrated better performance of non-linear, non-parametric models. In particular, it was shown that some rules of thumb were quite effective during the time span considered – for example, the completely non-diversified portfolio consisting of a single risky asset was best in the forecast using nearest-neighbor estimates.

The estimates of expected returns and volatilities of various GKO issues were constructed and compared, and it was shown that the dynamics differed dramatically across the periods of alternative debt issue policies. The authors demonstrated that, starting in 1997, accounting for interactions with other segments of the Russian and world markets became indispensable for efficient forecasting and decision-making in the GKO market.

It is a limitation of the project that it deals only with the analysis of short-term market fluctuations and efficiency of speculative investments. The problems related to GKO market instability, which ultimately brought about its collapse, are only tangentially discussed. Undoubtedly, there remains a huge scope for the quantitative research of this inherent instability that could fruitfully explore both Russian and other emerging markets data.

1. INTRODUCTION

The transition from a centralised and military-oriented economy to the market one cost Russia a huge budget deficit (1-2 bn. US dollars monthly). The state was impelled to guarantee a minimum level of private consumption and was burdened with very high expenses related to an over-slow reorganisation of the military sphere (maintenance of mobilisation reserves in industry, provision of quit officers etc.). At the same time, the income-providing tax system was not adapted to the rapid process of the privatisation and development of the small business sector. By 1994, the budget deficit had been covered only through the issuing of more money, with the natural result in the form of a high rate of inflation. That policy completely changed after the organisation of the state bond (GKO-OFZ) market. The market was established in the middle of 1993 and developed very rapidly. By the middle of 1994, the issuing of new money was suspended and the accumulated deficit was transformed into state debt. No attempts were undertaken to combine the issuing of money and bonds, so the volume of state debt grew in the form of the budget deficit, which exceeded 70 bn. dollars at the beginning of 1998. To ensure the placement of the bonds, the issuer (the Russian Ministry of Finance) had to agree to a very high per cent rate on borrowings (up to 100 per cent over the real interest rate) and shorten the period to maturity (3-month GKOs were mainly used up to 1997). Thus, the high yield to maturity attracted some foreign investors, supported by the Russian government. Almost all formal restrictions imposed on the activity of non-residents were eased in 1997 and, as a result, about one-third of the Russian bond market belonged to foreign speculative capital (the problem of borrowing in hard currency has to be considered separately). Such a situation determined the strong dependence of the Russian market on the behaviour of the world financial system. Initially (from the end of 1996 to the 1st half of 1997), the attraction of foreign capital played a positive role, facilitating the stabilisation of the market and lowering the real per cent rate almost to 10 per cent. However, the world financial crisis, which has been going on since October 1997, has had catastrophic consequences for almost all countries with unstable economies, and the Russian GKO market crashed in August 1998.

Such a short and dramatic history of the GKO market is an important case of the behaviour of emerging markets and is worthy of thorough research investigation.

In view of its non-stationarity and high volatility, the Russian state bond market differs essentially from the corresponding markets of countries with developed market economies, first of all from the US market which was taken as a prototype. Unlike US Treasury bills, it was impossible to consider Russian GKOs as risk-free securities and, from the very beginning of the Russian market evolution, GKOs were used not only for hedging but also, even preferably, as instruments of active speculation. Due to this, the known methods of the analysis of the state bonds market have to be modified and their efficiency has to be checked against a database of the Russian market.

The results obtained in the project are presented according to the following schema. First of all, a brief review of the literature is given (Section 2). The succeeding basic material is divided into two parts. The first part (Section 3) is devoted to the qualitative and quantitative description of market behaviour in the round, defined by the yield to maturity (YTM) index. The main stages of the evolution of the market are detected and the analysis of its crash in 1998 is given. The scheme for arbitrage between GKO and hard currency investments is introduced. Correlation and regression analysis confirmed that the dynamics of GKO returns were, to a greater extent, connected with the dynamics of the returns from currency investments, and, to a lesser extent, with the volume of the bonds in issue. Some algorithms of one month forward forecasting for an average yield, taking into account the formalised factor of political instability, are designed and tested. The second part (Section 4) contains a structural statistical analysis of the market, where the main attention is paid to research into the efficiency of short-term speculative operations, related to the fast re-allocation of investments between different GKO issues and hard currency.

An evolution series scheme is proposed that allows an analysis of the statistical properties of the yields of various GKO issues. This analysis demonstrated that random walk modelling is not adequate and that returns can be forecasted using the evolution series. The results of the testing of various forecasting algorithms are described and the advantage of schemes taking into account the non-normality of time series (reflecting the crucial role of a small number of market agents) is confirmed. An example is given demonstrating the importance of the usage of all information related not only to the history of the GKO market but also to the history of other markets. After that, the general scheme of portfolio management rules is given for the non-stationary market. The scheme is based on adaptive forecasting algorithms, which take into account all the information available to investors, and on the solution of the optimisation problem. The results of the testing of decision-making rules during the different stages of market evolution are demonstrated.

For the period of 1996, when the GKO market per cent rate was at its highest, a statistical database in the form of an evolution series was used. The

dynamics of portfolio structure are presented in detail. For later periods, the aggregate rules for the allocation of assets between the groups of issues with various periods to maturity and hard currency investment (in US dollars) are both established. Due to market non-stationarity, the decision rules changed, taking into account new essential information factors. In all cases, the designed rules allowed people to «beat» the market, exceeding the average level of returns from speculative operations, which was itself extremely high.
The summary of the main results and some qualitative recommendations are presented in conclusion. The Appendix contains information on the statistical data used and provides more detailed information on the results of decision-rules monitoring.

2. REVIEW OF LITERATURE

World literature (mainly, English and American) on the problems of state bonds policy is rather vast. A sufficiently exhaustive review of the qualitative aspects of the state debt problem is contained in Sunararajan et al, 1997, reflecting the viewpoint of the International Monetary Fund. The quantitative aspects of the state debt topic are traditional for macroeconomic research (see, for example, Haliasses and Tobin, 1990). As a rule, its analysis includes general macroeconomical modelling and is oriented to a static consideration. Possibly the best surveys of market analysis are given in the well-known books (Sharp and Alexander, 1990; Sinkey, 1992). It is necessary to mention also the popular books (Fabozzi, 1996; Fabozzi at al, 1994). Much attention is paid to the theories of percentage rate time structure (i.e., to the yield curve behaviour) in accordance with the classical models (Lutz, 1940; Hicks, 1946; Modigliani and Sutch, 1966). At the same time, the statistical falsity of these theories is well-known. Most theories consider state bonds as risk-free, used for the hedging of the flow of obligatory payments (see, for example, Zenious, 1995). Sometimes, restraints on duration are introduced in order to take into account the interest rate risk, although this measure is known to be insufficient.
More practically-oriented research can be found (Kariya, 1993; Grinold and Kahn, 1995). Kariya formulates the problem of the estimation of the evolution of yield to maturity as a non-stationary stochastic process and models this function as a combination of a polynomial trend and a linear regression of some factors. It is natural that YTM forecasting is equivalent to prices forecasting. However, the error of computation of the return from speculative operations, as a difference from the prices forecasts for the nearest dates, may

be large enough. Investigations by the BARRA group, partially presented in Grinold and Kahn (1995), are oriented to serve large investment funds which do not participate in short-term speculations but are interested in the forecasting of long-term investment efficiency. Therefore their main attention was paid to the estimation of coupon bonds returns and the calculations of net present value.

Unfortunately, the immediate application of the foreign research to the Russian financial market is not possible because of its non-stationarity and strongly fluctuating behaviour. At the same time, the methods elaborated for the analysis of the behaviour of very risky securities appear to be of great interest. Especially, these refer to the research into heteroscedastic models, started in the paper by Engle (1982) and thoroughly described in Gourieroux (1997). This author consistently develops the concept of forecasting as a conditional estimation and draws special attention to the peculiarities of financial series. Some useful information is also contained in an earlier published work (Taylor, 1986).

The research literature devoted to the Russian market is still rather poor and bears a descriptive character. In its general part, it reflects the normative documents of the RMFS, describes bond trades for organisational schemes, and gives a generalised picture of trading history and a qualitative analysis of the factors predetermining that history. However, there is a collection of articles (*GKO: Market Theory and Practice*, 1995) worth mentioning, especially A. Kucharev's article, in which the situation of the initial phase of market development (1993-1994) was analysed and attention drawn to the regulative role of the Central Bank credit rate. A large number of works that bear a prescriptional-advertising character are regularly published in the *Rinok cennih bumag* (*Securities Market*) magazine and we can point to the efforts of Gryadovaya, in which the strategies based on the YTM changes are recommended and analysed (see Gryadovaya, 1995). The article by Guberniev (1996) is also worth mentioning, in its attempt to apply the Markowitz procedure with a logarithmic utility function.

The methodology of investigation of the Russian state bonds market used in this project is, to a great extent, based on the results that were obtained earlier (Pervozvanski and Pervozvanskaja, 1993; Barinov, et al, 1997; Pervozvanski and Barinov, 1997; Pervozvanski, 1998).

3. STATE DEBT POLICY AND THE BEHAVIOUR OF THE MARKET AS A WHOLE

A) Policy characteristics and the basic stages of market development

Following Sundararajan at al (1997), let us present a general description of state debt policy. It consists of the formulation of debt management goals, the choice of financial instruments corresponding to those goals, and its co-ordination with money supply policy. Somewhat extending that concept, we can mention planning, which includes meeting budget requirements, and the creation of the state debt programme concerning the frequencies, volumes and types of issue. The internationally-accepted point of view is that the main objective of state debt policy is to cover state demand while minimising debt service cost (Sundararajan at al, 1997; Broker, 1993). At the same time, it is essential to note that the state debt problem in its general features coincides with the problem of the management of the liabilities of any financial organisation, the main aspects of which are the choice of the level of interest rates necessary to attract capital in the competitive investments market (Koch, 1988), and the choice of risk exposure related to the fact that investors could withdraw their capital regardless of interest rates.

We now further describe the main features of Russian state debt policy. According to the IMF recommendations, the policy of the Ministry of Finance (MFRF) was subordinated to a single goal, that is, to provide full coverage for the state budget deficit without additional money supply. More exactly, any issue must be sterilised and taken out of circulation by its transfer into state debt. The classical problem of economic theory (see, for example, Haliasses and Tobin, 1990), related to the transfer of the deficit burden on to future generations, was unlikely to play an essential role in the policy of the issuer. The main task consisted only in making the system a self-financing one.

Four general stages can be distinguished in policy development:

- initial development and expansion
- dominance of the internal financial market (from 1995 to the 2nd half of 1996)
- stabilisation and unification with the world market (from the 2nd half of 1996 until 1997)
- destabilisation after the beginning of the world financial crisis (October 1997) and the collapse of the market (July-August 1998)

At the first stage, the organisational structure of the market was elaborated and the capacity for issues increased; therefore the yield became higher than in the hard currency market. By the end of that stage, it turned out to cover fully the budget deficit due to the issuing of debt, and the liquid assets of commercial banks were transferred from hard currency to the higher-yield GKO. The internal inflation rate decreased significantly, as did the hard currency rate. The latter led to a decrease in the competitive ability of the hard currency market, and allowed the solving of the task of financing the budget deficit with a lower yield level (80-100 per cent per year) at the second stage. The only exception was the final period (March-July 1996), when the Presidential campaign forced a rapid growth in state expenditure with a corresponding growth in GKO issues. The political instability caused a rise in risk-premium investments in Russian securities.

The 3rd stage is characterised by the strengthening of government financial policy and the decrease in political risk, which allowed the yield to drop to 50 per cent by the end of 1996. Nevertheless, the exchange rate being low (less than 15 per cent per annum following the previous trend), GKO investments were highly profitable. That caused the rapid growth of investment in the Russian market by non-residents. During the first half of 1997 alone, the investment of non-residents in the GKO market increased six-fold. After the appropriate international rating was awarded to Russia, it became possible to realise the issue of Russian bonds in the external market with an essentially lower percentage rate (10-12 per cent per annum). That, in turn, led to a fall in the yield to 18-20 per cent in the internal market by October 1997, demonstrating almost absolute parity of yield between bonds denominated in roubles and hard currency, taking into account the 5-6 per cent annual growth in the exchange rate.

Internal investors reacted by a partial transfer of capital into the stock market, which was providing a very high profit at that time (300 per cent per annum and higher). Moreover, many big commercial banks (ONEKSIM, MFK, Menatep etc.) significantly reduced their investment in the GKO and focused their activity instead on short-term investment in corporation stocks, capturing the controlling interests in order to form financial-industrial groups. The stock market appeared to be attractive also for non-resident investors pursuing mainly speculative aims.

Thus, an interrelationship was formed between the two sectors of the internal market (bonds and stocks), and between the internal and the world markets. Moreover, although residents considered the state bond market to be very reliable, for non-resident investors, it remained one of the most risky emerging markets. This circumstance was clearly manifested in the period of world financial crisis at the end of 1997.

Besides, in 1997 the credit policy of the Central Bank significantly changed. Unlike the 1995-1996 period, when the Central Bank credit rate played a restrictive role (up to 200 per cent a year), being essentially higher than the bond yield, it strongly decreased in 1997 and became one of the market-regulating factors.

Unfortunately, money supply policy was permanently strict, although many experts warned of its danger (see, in particular, Pervozvanski, 1996). At the same time, the Russian financial system faced a lack of hard currency due to the decrease in world oil and gas prices and became more oriented to external currency borrowings. Already by July 1997, the currency balance of the commercial banks had become negative (by 1.4 bn. dollars). In consequence, the significant part of currency credits belonging to the banks was guaranteed by the GKO. This strengthened the degree of dependency of the GKO market on foreign investors.

In October 1997, the world financial crisis exploded. Investors started to withdraw their capital from all the emerging markets of countries which had developed themselves by means of foreign credit, Russia among them. This process developed as follows. First of all, foreign investments were withdrawn from the corporate stock market. Domestic investors also followed them, although the greater part of their capital was transferred to the GKO market, which delayed its collapse. Nevertheless, with foreign investors leaving the GKO market, prices fell with the decline in demand. In order to avoid the creation of a «money machine» by the banks, the CBRF (the Central Bank of the Russian Federation) was forced to increase strongly the refinancing rate. The transfer of commercial bank capital into super-profitable short term issues has essentially increased the cost of debt service. The GKO system has ceased to bring any profit to the budget and, what is more, it appears to be unable to finance itself. The government made attempts to cover the deficit with IMF and World Bank loans. After the first transfer had been received, the CBRF announced the cessation of the issuing of short-term bonds and the partial transformation of debt into long-term borrowings (July 1998). However, the volume of mature short-term bonds exceeded government possibilities and the Ministry of Finance and the CBRF announced in August a refusal to fulfil their obligations.

The financial crisis in Russia needs special detailed analysis, which is out of the scope of this particular project. However, one should note that the crash of the GKO system was caused precisely by the main principle of policy – the compensation of the budget deficit without increases in the money supply. Up to the middle of 1997, the policy was justified by the high positive trade balance, accompanied by an intensive hard currency inflow into Russia. As soon as the fall of the world prices of energy resources and metals had occurred, that inflow strongly reduced. The monetary policy of the CBRF became senseless as it continued to stimulate imports. But, without the printing of more money and the corresponding rouble devaluation, it was impossible to retain the currency reserves not only of the CBRF itself, but also of the banking system as a whole. Inflation was the inevitable consequence of an export structure oriented towards raw materials, given the decline in their prices. Artificial dampening of inflation led only to catastrophic collapse instead of the relatively slow growth in the exchange rate with the possible adaptation of the financial-economic system to new conditions. The GKO crash might have preceded the splash of inflation, but it was actually caused by plausible inflationary expectations. Moreover, the liberalisation of restrictions on the participation of non-residents in the GKO market and its internationalisation reduced the stability of that market with respect to the hard currency market. Note also that the whole period is characterised by high political instability.

Summing up this analysis of the evolution of the GKO market, the following qualitative conclusions can be made:

- during the 1st stage, the competition between bond and hard currency markets was the main factor that determined the market yield;
- during the 2nd stage, the state bond market began to prevail over the other sectors of the internal market, attracting almost all investment potential; the market rate of return was mainly determined by the issuing activity; and the comparative yield of various GKO issues was the only subject of interest for the internal investor;
- competition, not only with the hard currency market but also with the corporate stock market, determined the GKO yield during the 3rd stage, which also depended both on the credit policy of the Central Bank and world market behaviour;
- in the 4th stage, the behaviour of the world market and the related behaviour of the domestic hard currency market played the dominant role.

It is natural that, during all the stages of the development of the GKO market, the main factor was the state of the budget deficit which, in its turn, determined the more clearly observed processes in the financial markets.

B) The interrelationship between the state debt policy and the yield index

The GKO market return index depends on a number of factors. Let us analyse its behaviour using the monthly data of mean YTM, so that short-term fluctuations are excluded.
First we shall describe the qualitative reasons determining the model structure. It is assumed that the dynamics of the YTM index I_t depend on the relationship between demand and supply. We shall take the ratio of issue b_t and money supply M_t for the characteristics of the intensity of supply.
The intensity of demand, as it has already been specified, is determined, mainly, by competition between the bond market and the currency market. In particular, one can assume that, at a constant level of supply, an equilibrium relationship takes place:

$$I_t = r_t + e_t + l_t,$$

where e_t is the rate of growth in the exchange rate and:

$$e_t = \frac{S_t - S_{t-1}}{S_{t-1}},$$

S_t - exchange rate (rouble / dollar),
r_t - currency deposits interest rate,
l_t - conditional parameter characterising the insurance of the investor from rate instability.
To confirm statistically this hypothesis, first of all a correlation analysis was conducted.
It turned out (see Table 1) that the yield index strongly correlates with the factor $r_t + e_t$. At the same time, the relationship between the yield and the issue volume appeared unexpectedly weak. In other words, the market adapted to competitive equilibrium rather quickly. In order to provide a more thorough research of the relationship, a number of regression models were built. With that, special attention was paid to the political instability factor, which was formalised by the dummy variable f_t, equal to 0 in calm situations and up to 1 during a period of volatility, so that:

$$l_t = l_0 + a_5 f_t$$

where a_5 is an estimated positive constant.
The following cases were considered:

a) $f_t = 1$ in March-July 1996 and at the end of 1997;

b) $f_t = 0.5$ in March-April and July 1996 , and

$f_t = 1$ in May-June 1996 and at the end of 1997 i.e., in the most tense periods.

Table 1. Correlation of yield index with factors.

	I_t	*b/M2*	$r_t + e_t$	f_t
I_t	1			
b/M2	0.186473	1		
$r_t + e_t$	0.817938	0.152807	1	
f_t	0.837962	0.245171	0.658114	1

Further exploration was conducted for case (a). That factor was either added to one of the main factors, or to their combination, while a logarithmic model appeared most adequate:

$$\log I_t = a_1 \log e_t + a_2 \log\left(b_t / M_t \right) + a_3 f_t + \varepsilon_t$$

where ε_t is a random error.

The results of the calculations are given in Table 2.

Table 2. Regression statistics.

Variable	Coefficient	Std.Error	t-value	t-prob	PartR^2
logb/M2	1.3613	0.087029	15.642	0.0000	0.9495
f_t	0.61280	0.37892	1.617	0.1298	0.1675

R^2 = 0.957264 \sigma = 0.662844 DW = 0.908

Variable	Coefficient	Std.Error	t-value	t-prob	PartR^2
log e_t	0.72535	0.023877	30.378	0.0000	0.9861
f_t	0.93930	0.20332	4.620	0.0005	0.6215

R^2 = 0.988233 sigma = 0.347813 DW = 2.02

The estimates of the parameters were obtained on the sample for the first 15 months, and the forecasting ability of the model was tested on the remaining data.

It is obvious that the highest accuracy takes place under the simplest model where the leading factor is the return on the exchange rate. Thus, statistical analysis confirmed the assumption that competition between the GKO market and the hard currency market played the main role in the determination of the behaviour of the GKO market.

C) Mean-term forecasting

The long-term forecast of the state of the market is impossible without modelling the socio-political system as a whole. Therefore we tried to obtain the mean-term forecast (one month forward) on the basis of current financial information alone. We took for a basis the relationship between the GKO YTM index and the factors determining demand and supply in the market. However, to design forecasting models, it is essential to take into account market inertia, i.e. the dependence of returns on their preceding values.
All the above-mentioned factors contribute towards the following structure of an autoregressive model:

$$I_{t+1} = a_0 + a_1 \frac{b_t}{M_t} + a_2 e_t + a_3 r_t + a_4 I_t + l_t + \varepsilon_t , \qquad (1)$$

where $a_i > 0, \quad i = 1,\ldots,4$, and ε_t is a forecasting error.
Looking at linear models, the simplest one appeared to be the best one:

Model 1:
$$I_t = a_1 I_{t-1} + a_2 f_t + \varepsilon_t$$

The application of regression techniques to logarithms of the original variables turned out to be more successful. The best model has the form:

Model 2:
$$\log I_t = a_1 \log I_{t-1} + a_2 \left(f_t + 1 \right) + a_3 \left[\log\left(\frac{b}{M} \right) \right]_{t-1} + a_4 \log\left(e \right)_{t-1}$$

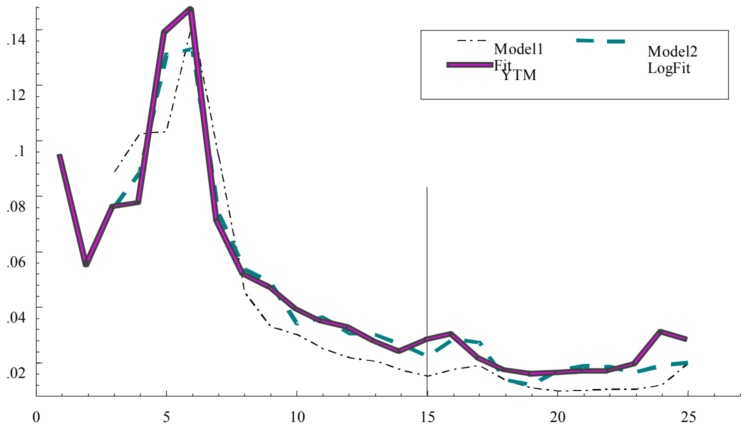
Table 3 contains the estimation results for both the described models. Estimates of the parameters and their standard deviations, as well as statistical criteria, are shown.

Table 3. Estimation results for regression models.

	a_1	a_2	a_3	a_4	R^2	DW	SC
Model 1	0.6047 [0.1804]	0.05723 [0.02232]	-	-	0.955	2.08	-7.413
Model 2	0.4985 [0.0819]	-	0.3273 [0.0900]	0.2348 [0.0535]	0.999	2.18	-3.810

Figure 1 and Table 4 illustrate the results of adjustment and one month ahead forecasting for models 1 and 2 (parameters were estimated using data for the first 15 months and then these were used for forecasting over the next 10 months). One can see that the second model is obviously better.

Figure 1. Adjustment and forecasting by Models 1 and 2.



Real behaviour predicted using Model 2 was within the confidence region except for last two months relating to the beginning of the financial crisis, when the model obviously gave estimates that were too low.

Unfortunately the authors do not have data on issue policy during the further development of the financial crisis. However, it is clear that the stability of the model cannot be guaranteed in such a long and volatile period. And, what is more, it was impossible to provide a statistical prediction of the final collapse of the market without taking into account such fundamental factors as the state of the external accounts and the schedule of loan payments.

Table 4. Results for Models 1 and 2.

DATE	YTM	MODEL1	MODEL2
01.01.96	0.0941	-	-
01.02.96	0.0545	-	-
01.03.96	0.0757	0.0889	0.0764
01.04.96	0.0770	0.1026	0.0887
01.05.96	0.1383	0.1034	0.1312
01.06.96	0.1468	0.1429	0.1332
01.07.96	0.0708	0.0945	0.0740
01.08.96	0.0514	0.0456	0.0538
01.09.96	0.0468	0.0331	0.0488
01.10.96	0.0389	0.0301	0.0341
01.11.96	0.0343	0.0251	0.0364
01.12.96	0.0323	0.0221	0.0309
01.01.97	0.0273	0.0208	0.0302
01.02.97	0.0236	0.0176	0.0265
01.03.97	0.0277	0.0152	0.0223
01.04.97	0.0298	0.0178	0.0286
01.05.97	0.0213	0.0192	0.0273
01.06.97	0.0168	0.0137	0.0139
01.07.97	0.0153	0.0108	0.0120
01.08.97	0.0158	0.0099	0.0173
01.09.97	0.0164	0.0101	0.0190
01.10.97	0.0165	0.0106	0.0185
01.11.97	0.0188	0.0106	0.0167
01.12.97	0.0305	0.0121	0.0190
01.01.98	0.0278	0.0196	0.0201

Summing up the results for this chapter, we make the following conclusions:

- state debt policy during the period 1993-1997 bore an inflexible character and was directed towards the full coverage of the constantly high deficit in the state budget without additional money supply
- GKO yield and, consequently, the cost of the internal state debt service, were determined mainly by competition with the hard currency market

and, to a sufficiently less extent, by the volume of GKO issues; as a rule, the GKO yield was strongly above the yield of investment into hard currency

- market yield could be forecasted with satisfactory accuracy up to the beginning of the world financial crisis
- the GKO market crash had a systemic character and was conditioned by the crisis in the currency market which was, in its turn, predetermined by the character of an export orientation towards raw materials and the strong decline in their world prices
- the sensibility of the internal state debt market with respect to the behaviour of the world market increased with the growth of the participation of non-residents in the market.

4. SHORT-TERM SPECULATIVE INVESTMENT RETURNS

A) Problem statement and statistical analysis

As it was specified in the Introduction, the GKO market was used mainly for short-term speculative operations, where capital was quickly re-allocated between investments in different GKO issues or was converted into hard currency. We could suppose that the returns on such investments be considered as random values, so that the efficiency of the speculation could be estimated statistically. Evidently, results depend on the decision rules used by investors.

Perhaps it is most interesting to estimate an upper level which can be achieved with the use of the most rational decision rules resulting from the modern theory of portfolio investment in risky securities. In view of the above, an essential part of our further material bears a purely technical character and formalizes the procedures of forecasting and decision-making. After that, the efficiency of the speculative game at different stages of the development of the financial market will be estimated.

A decision rule is understood as an algorithm allowing the choice of a structure of investment portfolio x_t at any moment t on the basis of information y_t available to the investor at that moment. The portfolio structure is a vector the components of which x_{jt} are the capital invested into

this or that asset. In the present case, the various bond issues and hard currency (USD) are considered as possible assets.
The choice rule for structure x suggested by the classical optimal portfolio theory for risky investment is the solution to the quadratic programming problem:

$$\text{Max } \left\{m^T x + r_0 x_0 - \lambda x^T V x / I^T x + x_0 = 1\right\},$$

where x_0 is the portion of risk-free investments with the return τ_0
m - vector of the expected returns of investment in risky securities,
V - covariation matrix of the deviation of returns from the expected values,
λ - parameter determining the propensity of an investor to averse risk.
In the modern interpretation (Gourieroux, 1997; Pervozvanski, 1997), the expected return m is interpreted as the return forecast at the moment of decision-making, taking into account the information available to an investor, while matrix V is defined by the statistics of forecasting errors. It is that very fact that predetermines the importance of information concerning the factors influencing market behaviour and, consequently, the forecast of returns.
A formalised forecast can be based only on a statistically verified model. However, it is necessary to emphasise the difference between forecasting models and the models of functional relationships. In practice, speculative market agents, when making their market forecasts, base them mainly on technical analysis. The latter is the concept that asserts that the price history for a certain security includes all the necessary information to forecast the behaviour of the price in the future. Within the framework of this project, the concept of technical analysis is also used, but treated in the wider form: the forecast of the returns on short-term operations for each risky security can be determined not only by the history of the security, but also by the history of all other securities sold in the interrelated financial markets.
According to the results of qualitative consideration conducted above, one can assume that the return forecast for each GKO issue during the period 1995-96 requires an account of the histories of all other issues and, probably, the exchange market. Since 1997, it is also essential to take into consideration the behaviour of the CBRF credit rates, the corporate stock market and the world market.
One should also point out some specific difficulties arising from the tentative concept of considering the GKO as risky securities based on the statistical characteristics of their returns.

The complexity of the problem is caused by the fact that the time series of bonds sales data is short by definition, and therefore any estimations related to the issue of any specific bond are not precise.

To overcome that obstacle, we have suggested (Pervozvanski et al, 1997) a scheme for the transformation of the original series into an evolution series (ES). Each ES consists of segments of series, corresponding to different original series, united in such a way that the 1st ES includes the history of segments of issues which are furthest to maturity at any time t . The 2nd ES includes the segments for issues which are next to the 1st in relation to maturity, and so on.

The given period of any evolution series is close to that of the market as a whole, allowing an acceptable basis for statistical conclusions. At the same time, the forecasting of the ES facilitates forecasting for any issue. The alternative way is more traditional and consists of the formation of returns indices by groups of issues, e.g., a group with a time to maturity of less than one month, from one to three months, and so on. It is obvious that, in that case, the possibility of individual forecasting is lost and hence the decision rules, formed on the basis of the forecast, can bear only an aggregate character.

Before constructing the forecasting schemes, preliminary statistical processing was carried out in order to check the validity of the main hypotheses of classical financial market theory which form the foundation of Random Walk Modelling (RWM). Namely, these are the hypotheses of stationarity, normality and non-correlation.

The hypotheses have been checked in relation to the evolution series, designed on the basis of the series of the returns for one-day operations for every original issue, i.e.:

$$f_i(t) = r_i(t) = \frac{P_i(t+1) - P_i(t)}{P_i(t)} \approx \ln \frac{P_i(t+1)}{P_i(t)}$$

where $P_i(t)$ - sale price on day t .

The original empirical material included information on sales during the period 18.05.94 – 01.08.97. Based upon this data, five samples of the evolution series ESIJ, I=1,...5, J=1,...,N were formed (see Appendix B).

Each sample included several (N) evolution series, the number of which grew strongly in 1997 (ES5), due to an increase of the frequency of issues and a prolongation of the time to maturity.

For all the samples the following descriptive statistics have been calculated: μ - mean; σ - standard deviation; b - asymmetry; k - excess kurtosis; minimum ($\min$) and maximum ($\max$) values; and a normality test (χ^2) of the $T/_6\, b + T/_{24}\, k$ type. In addition, histograms in comparison to the normal distribution density with the same σ have been built. Some of the results of the calculations are represented in Appendix C.

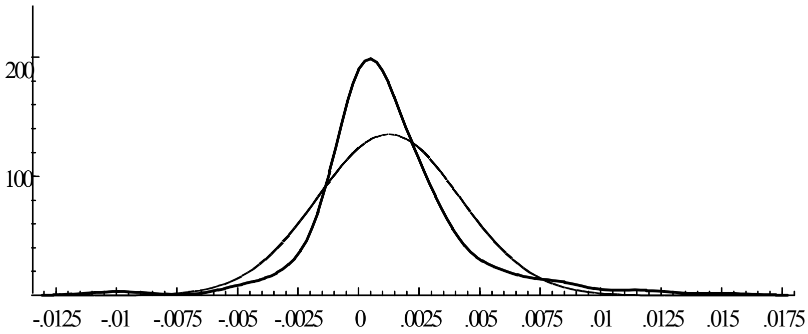
Table 5. Data on the samples of evolution series.

Sample	Number of points	Period	Number of ES in a sample
ES1	229	18.05.94-01.01.95	6
ES2	230	02.01.95-19.08.95	6
ES3	230	20.08.95-05.04.96	6
ES4	238	06.04.96-29.11.96	6
ES5	212	01.01.97-01.08.97	26

The statistical data demonstrate the non-stationarity of sequences: the values of m, σ calculated for any evolution series essentially depend on the number in the sample τ, i.e. in the period of the market activity. The market was developing in the direction of a lower value in the expected returns and a lower volatility in 1997. It is natural that the issues nearest to maturity have a lower volatility than those which are further away. However, the risk degree of the operations characterised by the relation σ / μ was unstable. Some formal non-stationarity tests have also been performed: F - $test$, to check the equality of the standard deviations; and t - $test$, to check the equality of the means (see Appendix C).

The estimates of asymmetry and excess coefficients allow us to make two conclusions: on the one hand, there are considerable deviations from normality; on the other hand, although a certain tendency to the decrease of these deviations is observed, they still remain essential (χ^2-test rejects normality for all series, see Appendix C). The deviations from normality, appearing in the form of «long tails» of the distributions, are clearly seen in a histogram, an example of which is given in Figure 2.

Figure 2. Example of distribution of the evolution series.



The most important statistics, allowing us to estimate the usefulness of the Random Walk Model, are the autocorrelation of returns. Table 6 presents data for some of the samples.

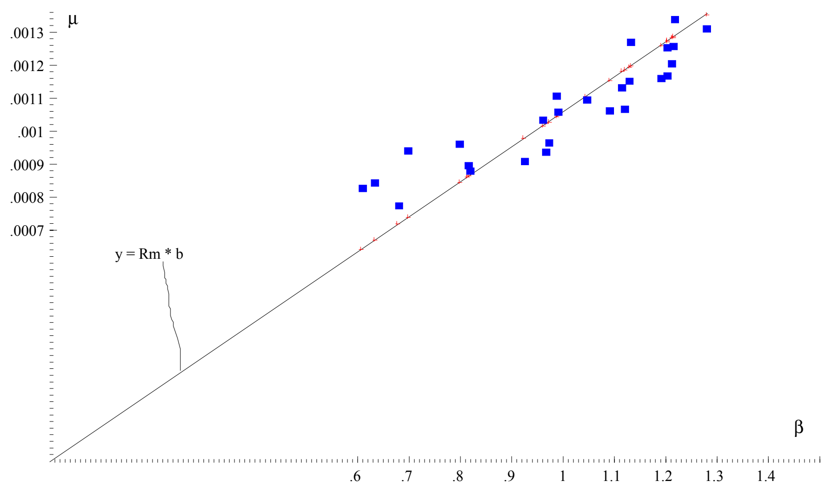
Table 6. Autocorrelation for some samples of evolution series.

t	ES1	ES2	ES3	ES4	ES5
1	0.31	0.26	0.15	0.30	0.28
2	0.12	0.005	0.03	-0.03	0.04
3	0.0	0.027	0.001	-0.05	0.02
4	-0.1	-0.16	-0.09	-0.15	-0.11
5	-0.05	-0.01	0.12	-0.11	-0.06
6	0.20	0.15	-0.03	-0.18	0.15
7	0.08	0.15	0.1	0.21	0.13
8	-0.07	-0.12	-0.04	0.01	-0.13

It demonstrates evident correlation with lags of 1 and 7, confirmed also by spectral analysis.
Summarising the results of preliminary statistical analysis, one can make the following main conclusions: a) real market behaviour can not be described

using an RWM-type model; b) short-term forecasting of speculative operations returns is possible; c) forecasting schemes must take into account the non-stationarity and the non-Gaussian character of fluctuations in returns.
Let us note that the absence of normality is a natural consequence of a market structure. Gaussian behaviour would take place if there were a lot of independent agents having approximately the same market power. However, only three or four agents dominate the GKO-OFZ market (first of all, Sberbank, then Centrobank and Orgbank) and control more than one-half of its volume. There may exist other rational explanations of the «long tails» effect (see, e.g., Bak, 1996).
We now consider the degree of interrelationship between the evolution series, which is also of great importance for the estimate of forecasting possibility. An essential interrelation between the analysed sequences has been established (the correlation level is equal to 0.8-0.9). It can also be illustrated by analysing the relationship between the sequences and the market indices. Figure 3 presents data on CAPM testing for the market under consideration. It is interesting that values μ_j and β_j, calculated according to the evolution series for 1997 (ES5), fit the straight line (market line) rather well, with the exception of those issues which are the closest to maturity and therefore less volatile.

Figure 3. CAPM-testing of the market.



To a certain extent, the CAPM-test also indicates that the Russian market is in the process of development, tending to reach higher efficiency. Extreme growth in a number of simultaneous issues, and a consequent growth in the number of evolution series, a part of which has a short history, raises a problem of series aggregation, which is considered in detail below. Here, one should only mention that all the series (except the farthest ones), are mainly correlated with the closest ones, i.e. assets that are weakly risky.

B) Forecasting Models

Consider a rather general forecasting model in the form:

$$R_t = G(y_t) + e_t(y_t) \tag{1}$$

where R_t is a vector the components of which are the returns on investment in various types of securities, $j = 1,\ldots,n$, bought at the moment t and sold after a fixed interval (day, week), which is further formally taken as a time unit. The vector y_t stands for a set of all the information factors available to the investor up to the time t of the decision. In particular, due to the autocorrelation of R_t, it is reasonable to include in y_t the known history of returns, $R_{t-1}, R_{t-2},\ldots,$ and perhaps the histories of some other factors which may influence the evolution of the bond market (see above).
The function G is supposed to be explicitly independent of t. The values $\{e_t\}$ are random and mutually independent (discrete «white noise») but their distributions may depend on y_t.
Following from (1):

$$\hat{R}_t = G(y_t) \tag{2}$$

is the best forecast of the return based on information y_t, and e_t is the forecasting error.
For verification of model (1), it is necessary to estimate $G(y_t)$ and some characteristics of the conditional distribution of errors e_t.
In this paragraph we shall consider only the models of the following type:

$$G(y_t) = F(\theta, y_t)$$

where $F(.,.)$ is a function of the given type, and θ are the estimated parameters.
The simplest kind is the linear (in parameters) autoregressive (AR) model:

$$G(y_t) = Qf(y_t)$$

where Q is a parameter matrix, and f is a given vector function.
If one uses only the histories of the forecasted returns, then:

$$R_t = A_0 + A_1 R_{t-1} + \ldots + A_l R_{t-l} + e_t = \hat{R}_t + e_t \ ,$$

where $A_i, i = 0, \ldots, l$ are the matrices of the parameters being estimated and e_t represents forecasting errors.
The number of parameters which have to be estimated is equal to $l\, n^2 + n(n+1)/2$. Under n ~10, $l = 2$ that number is comparable to the longitudes of ES which do not exceed the period of existence of the Russian market (~10^3 market days). Hence, it is reasonable to use a procedure allowing us to make the estimation more robust. First of all, it should acknowledge the principal component method (see Kariya, 1993; Pervozvanski and Barinov, 1997). Let us point out that, if $G(y_t) = const$ is accepted in model (1), and error distribution e_t is assumed to be independent of time, then we arrive at a classical RWM but with estimates which generally depend on the factors. In the applied theory of the securities market, there is a typical assumption that G is estimated as the mean of the history of the forecast process and that the error is a linear function of some external factors (see, e.g., Grinold and Kahn, 1995). The denial of RWM requires us to take into account the dependence of G on all known histories or, at least, on the value of R_{t-1}, observed at the previous moment of time.
The simplest class of such models has the form:

$$R_t = q_0 + q_1 R_{t-1} + e_t \tag{3}$$

If in addition we assume a diagonal form for matrix q_1, then we come to an independent, one-dimensional, one-step forecasting. One of the ways to improve the precision is to take into account the mutual influence of the forecasted series, i.e. to deny the diagonal form of q_1. Direct estimation requires us to estimate 27 parameters of histories with approximately 200 observations, but this is inefficient. For this reason, the principal components method has been applied. Ten components were required for the explanation to be within 90%. Analysis of the behaviour of the principal components is a special point of interest. First of all, it has been found out that the first principal component f_1 behaves practically as a simple index of market returns, i.e.:

$$I(t) = \frac{1}{N}\sum_{i=1}^{N} r_i(t)$$

The coefficient of the correlation between $I(t)$ and $f_1(t)$ is equal to 0.998. The last terms of the presentation:

$$r_i = q_{0,i} + q_{1,i} f_1 + e_j + \sum_{j=2}^{N} q_{ji} f_j$$

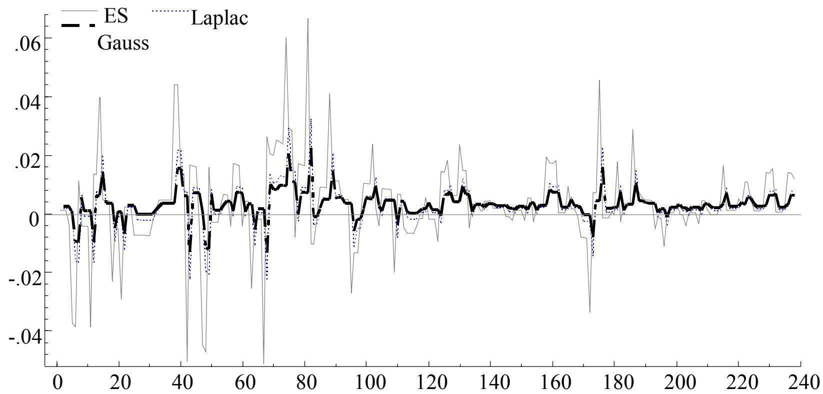
characterise the difference of that model from the model of a market line type. At the same time, specific calculations have shown that the usage of the multivariate time variance method (MTV), together with a least square estimation (LSE) of the principal component parameters, also does not lead to a fundamental improvement in the forecast.

The rejection of LSE appears to be more effective. As it is known, the LSE coincides with the maximum likelihood (ML) estimates under the condition that errors e_t be normally distributed. At the same time, as it was shown above, the hypothesis of normality is rejected for all the examined sequences.

The simplest class of distributions, reflecting the effect of the «long tails», is the Laplace distribution. For this class, the maximum likelihood of estimations is achieved by using the method of the least error modulus (LMM). This fact simplifies the parameter estimation. Figure 4 presents a graph of the true values of returns (ES) and the estimations $\hat{r}_G$ (predictor from the Gaussian errors model), $\hat{r}_L$ (predictor from the Laplace model). One can see that $\hat{r}_G$ provides a better tracing of peaks.

There are some other known ways to explain and to take into account the «long tails» effect. The method of the construction of conditional heteroscedastic (CH) models is the most popular in the world literature on financial series forecasting (Engle, 1982; Gourieroux, 1997). The main idea of the CH model is to take into account the dependence of volatility on forecasting errors during the previous time steps and, possibly, on the previous values of volatility itself.

Figure 4. Dynamics of real yield value and its estimates by Gaussian and Laplace models.



Formally, three important classes of CH model can be distinguished:

- ARCH (q) - Engle model (Engle, 1982):

$$\sigma_t = S_0 + \sum_{\tau=1}^{q} S_\tau \varepsilon_{t-\tau}^2, \quad S_\tau > 0$$

- GARCH (q, p) - Bollerslev model (Bollerslev, 1986):

$$\sigma_t = S_0 + \sum_{\tau=1}^{q} S_\tau \varepsilon_{t-\tau}^2 + \sum_{\tau=1}^{p} \gamma_\tau \sigma_{t-\tau}, \qquad S_\tau, \gamma_\tau > 0$$

- EGARCH - Nelson exponential model (Nelson, 1991):

$$\sigma_t = a e^{b\varepsilon_{t-1}}, \quad a > 0$$

In all cases, ε_t is interpreted as a deviation of returns from the expected value. If this deviation is positive, then it is taken as «good news», otherwise as «bad news». The Nelson model is the only one of the three considered models which takes into account the sign of ε_t and hence, the effect of asymmetry, the significance of which was mentioned above. One should emphasise that any type of CH model is able to explain the «long tails» effect (see Gourieroux, 1997).

As a rule, in the framework of the CH model, the histories mean or, more generally, the linear specification is used for, the estimation of an expected value. The only exception is the ARCH M model (Engle, Lilien and Robins, 1987) where σ_t is included in the number of explanatory variables. Such modification is motivated by the fact that, in cases of a greater uncertainty in the market, i.e. greater values of σ_t, market agents tend to realise their transactions with an additional risk premia. In all cases, CH models are non-linear as a whole, and the numerical procedures of parameter estimation, consisting of the approximate maximisation of the likelihood function on the set of parameters θ (Gourieroux, 1997), become more complicated. The *a priori* estimation of the possible efficiency of a CH model can be checked by the Lagrange multipliers test (LM test) (see, e.g., Ljung and Box, 1979). That test was performed on statistical data related to the bond market. For all the series under consideration, the test has confirmed the effect of heteroscedasticity. Along with this, it is practically important to find out to what extent accounting for the heteroscedastic effect increases forecasting efficiency. It turns out that, even in the best variants, this increase is inessential if GARCH models are used. For a group of samples, the Nelson model gives more interesting results. Preliminarily, it has been determined that there is a negative correlation between returns and volatilities in the considered sequences; for example, for ES3 it equals -0.45 and for ES5 it equals -0.40. In other words, the returns fall with the growth of volatility. And what is more essential, the relationships are not symmetric.

Figure 5 presents a so-called *News Impact Curve* (Engle and Ng, 1993), showing volatility σ_t as a function of ε_{t-1} for ES5. One can see that «good news» ($\varepsilon_t > 0$) does not stimulate market volatility. Only «bad news» has that property: the market «gets scared» of an unpredictable fall in returns.

Figure 5. News Impact Curve.

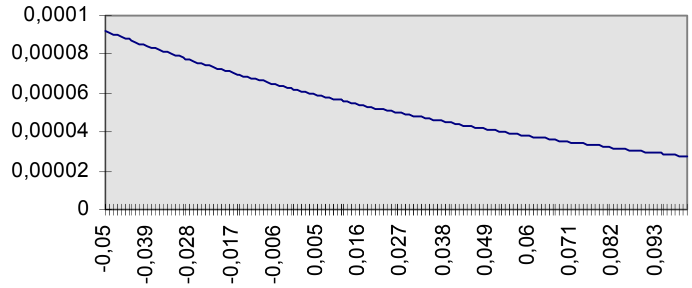


Table 7 presents the comparative results of the application of various forecasting methods to one of the evolution series in 1996.

Table 7. Forecasting methods comparisons.

	Nelson	MTV-AR	AR	Laplace	MTV-L	ARCH(1,1)
μ	0.002266	0.00279	0.00211	0.00192	0.00258	0.002558
σ	0.005022	0.00553	0.00495	0.00492	0.00561	0.004977

As is clear from the table, the best is the scheme of one-dimensional forecasting by the Laplace predictor.

Let us further estimate the capacities of the methods of non-parametric statistics.

We assume, as before, that the pairs { $y_\tau, R_\tau, \tau < t$ }, where y_τ is the values of the information factors and R_τ is the observed values of the returns, are known. It is necessary to give an estimation of returns $\hat{R}$ for the next period, using the history and the last information y_t. Formally, the parametrical model can be written as:

$$\hat{R}_t = F(y_t, \theta),$$

where the function F is considered as given, and the parameters θ are to be estimated from the given history. In schemes of non-parametric statistics (see,

e.g. Katkovnik, 1985; Butsev and Pervozvanski, 1995), the estimation $\hat{R}_t$ is formed directly on the basis of initial data.
The following estimations, which we shall formulate in terms of the problem under consideration, are the simplest and the most important ones in practice.

Nadaraya-Watson estimation:

$$\hat{R}_t = \frac{\sum_{\tau<t} \mu(|y_t - y_\tau|) R_\tau}{\sum_{\tau<t} \mu(|y_t - y_\tau|)},$$

where $\mu(\cdot)$ are the given decreasing functions (potentials). The speed of decrease in the potentials is a parameter of the algorithm.

Estimation by the "nearest neighbours" rule, realised with the help of the following procedure:

Let N values

$$d_\tau = |y_t - y_\tau|$$

be ordered so that

$$d_1 \le d_2 \le .... \le d_k \le \min_{\tau>N} d_\tau,$$

where k is a given number of "nearest neighbours", and is a parameter of the algorithm.
Then,

$$\hat{R}_t = \sum_{i=1}^{k} \rho_i R_i, \quad \sum_i \rho_i = 1, \quad \rho_i \ge 0,$$

where ρ_i are given weights, determined by a hypothesis concerning the local behaviour of R as a function of y.
The preliminary testing of the efficiency of non-parametric estimations was carried out on the same statistical basis as the testing of parametrical estimations described above. The corresponding data are shown in Table 8:

Table 8. Testing of the efficiency of nonparametric estimates.

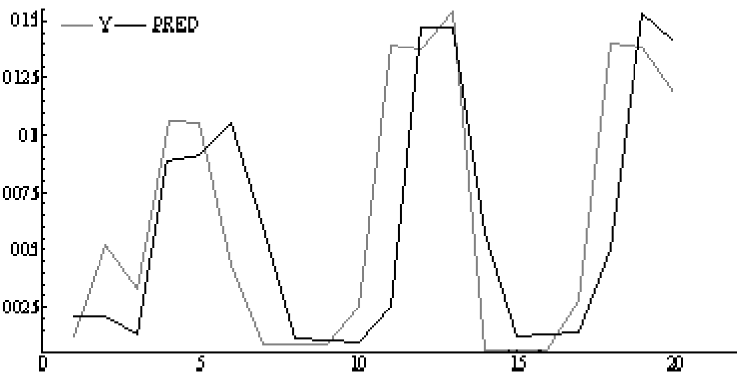
K	Weights	$\mu \times 10^{-3}$	$\sigma \times 10^{-3}$
10	parab.	1.81	4.93
	triang.	1.59	4.70
	uniform	2.23	5.21
6	parab.	0.80	4.65
	triang.	0.80	4.39
	uniform	0.86	5.93
5	parab.	0.76	4.34
	triang.	0.77	4.30
	uniform	0.94	5.05
4	parab.	0.60	4.24
	triang.	0.69	4.32
	uniform	0.44	4.19
3	parab.	0.79	4.55
	triang.	0.85	4.61
	uniform	0.69	4.42
2	parab.	1.01	5.03
	triang.	1.02	4.94
	uniform	1.01	5.13

The first column presents the number of nearest points; the second, the types of approximation weights; and the third and the fourth, respectively, the mean values and standard deviations of forecasting errors. The best parameter choice gives the result of (4.19, 0.44) which is essentially better than the results of parametric forecasting presented above in Table 6. The forecasting efficiency is also illustrated by Figure 6.

It is easy to see that the "nearest neighbours" rule can be interpreted as a generalisation of classical technical analysis based on the study of the similarity of current market behaviour to the earlier observed situations, represented in the form of charts of the volumes of prices and sales. If y_t includes only such factors, then the "nearest neighbours" rule formalises a procedure for the selection of similar situations and forecasting by "similarity".

Concluding the review of forecasting methods, let us emphasise that their efficiency is determined not only by the choice of algorithm but, to an even greater extent, by the choice of information factors. As specified above, since the end of 1996 the character of the interrelationship between the state bond market, other home market sectors and the world market has essentially changed. It was especially clear during the world financial crisis in the autumn of 1997.

Figure 6. Results of nonparametric forecasting.



As a result, we tried to construct short-term forecasting algorithms which take into account both the history of the bond market and the following factors:

- the Dow-Jones index as the characteristic of the world market
- the RTS index as the characteristic of the home market of corporate bonds
- the CBRF per cent interest rate as the characteristic of the credit market.

Linear regression models including various factors were used. The parameters were estimated for the period 10.09.97 - 22.10.97, preceding the beginning of the financial crisis. The models were compared by their forecasting efficiency during the period 23.10.97 - 31.10.97, i.e. the beginning of the development of the crisis.

From the very beginning, it turned out that the simultaneous consideration of the RTS and the Dow-Jones indices is inefficient in view of their close correlation (the shares market is extremely sensitive to world market signals). Therefore, our main attention focused on the models of the following types:

1. $R_t = \alpha_0 + \alpha_1 R_{t-1} + \alpha_2 YTM_{t-1} + \varepsilon_t$
2. $R_t = \alpha_0 + \alpha_1 R_{t-1} + \alpha_2 YTM_{t-1} + \alpha_3 DJ_{t-1} + \alpha_4 CBR_{t-1} + \varepsilon_t$

where R_t - GKO daily return index; YTM_t - yield to maturity; DJ_t - Dow-Jones index; and CBR_t - per cent interest rate.
The accuracy of the approximation on a trial sample is comparable for both the models. However, model 2 provided an obviously preferable earlier forecast of a strong market fall. The corresponding data are given in Table 9 and Figure 7.

Table 9.[*)] Results of the application of the model.

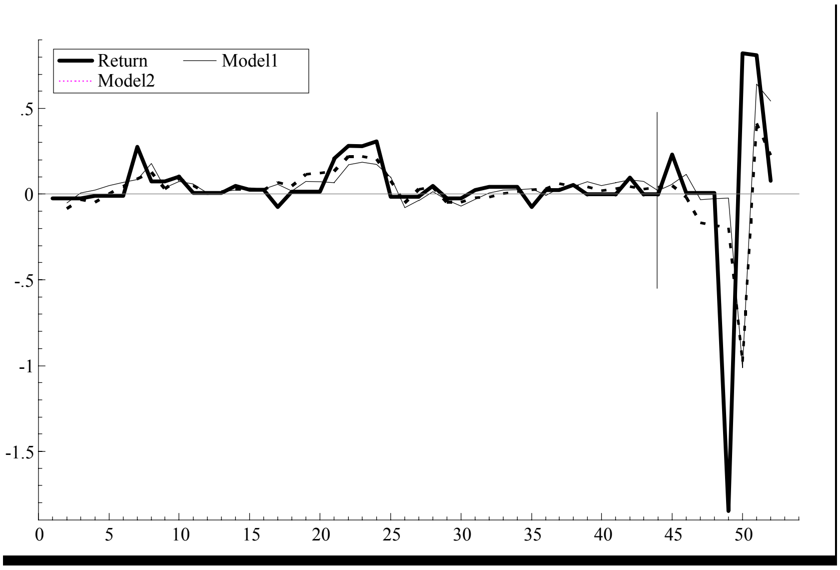
Model No.	Coefficient estimates	Test statistics
1	-0.92030 [0.35080] +0.66220 [0.20780] +0.05308 [0.02010]	R^2 = 0.42603, σ = 0.07207, s_{pred} = 0.87708 DW = 2.10, SC = -5.06
2	-5.72300 [1.66100] +0.61030 [0.15010] +0.08904 [0.02440] +0.00045 [0.00010] +0.02626 [0.01040]	R^2 = 0.55252, σ = 0.06533, σ_{pred} = 0.93453, DW = 2.07, SC = -5.14

Summing up the part of the report which covers the review and testing of the various formal schemes for short-term forecasting, some preliminary conclusions can be made:

- the important role in providing forecasting accuracy belongs to the choice of information factors and not only to the schemes themselves;
- preliminary testing shows the advantage of schemes which take into account a non-Gaussian character of the fluctuations caused by the market peculiarities specified above. The most useful schemes are Laplace and NNM predictors.

[*)] Standard errors for the coefficient estimates are given in square brackets.

Figure 7. Results of forecasting by Models 1 and 2.



Along with this, one should emphasise that forecasting is not an ultimate goal but it serves only as a means to provide information for decision-making rules. Therefore, any judgment concerning the advantages of this or that forecasting scheme can result only from an investigation of the efficiency of the rules of portfolio management which is based on the results of forecasting.

C) Decision Rules And Performance Evaluation

A decision rule could be defined as an algorithmically given mapping of the vector y_t of the information available to the investor at the moment of decision-making, into the vector x_t, defining the desired distribution of capital between various investment possibilities for the next time period.
According to the approach declared above, the construction of a decision rule breaks up into two stages:
Calculation of the forecast $\hat{R}_{t+1}$ of the investment return for the nearest interval and empirical estimation of a covariance matrix $\hat{V}_{t+1}$ of forecasting

errors basing on the samples of vectors $y_\tau, R_\tau, \tau \in [t, t-t_e]$, for a given window length t_e ;
Calculation of x_t as the solution of the Markovitz optimisation problem:

$$\max\left\{\hat{R}_{t+1}^T x - \lambda x^T \hat{V}_{t+1} x \;\middle|\; I^T x = 1,\ x \geq 0\right\}.$$

We can specify a formal scheme for the forecasting stage. Using parametrical estimations, the forecast is formed according to a formula of the following type:

$$\hat{R}_{t+1} = F\left(\hat{\theta}_t, y_t\right),$$

where $\hat{\theta}_t$ is an estimation of the model parameters for the sample $y_\tau, \tau \in [t, t-t_e]$.
As the sample is formed for a moving data window with length t_e, the parameter estimates change in time, i.e. the forecasting models are adaptive.
We would emphasise that, in contrast to our preceding publications (Pervozvanski and Barinov, 1997; Pervozvanski, 1997), we are not assuming here that the forecast is formed as an estimate of a conditional mean value. Actually, any forecasting algorithms can be interpreted only as methods of the interpolation of the functional relationship $y_t \to R_{t+1}$, based on empirical data.
The realisation of the described approach allows a great number of variants characterised by:

· the choice of an information vector y_t
· the choice of type of forecasting algorithm
· the choice of an estimation window of length t_e
· the choice of a risk aversion parameter λ.

A judgment about the practical efficiency of different decision rules can be obtained only by basing it on empirical data imitating the application of the rules in real speculative market conditions.
The most natural measure is the total yield of a self-financed portfolio for the rather long period T:

$$\hat{R}(T) = \sum_{t=1}^{T} (R_t, x_t),$$

where R_t is the vector of the returns on one-step operations, actually observed in the market, and x_t is the share of assets in the portfolio at time t.
The conclusion about the advantage of a certain rule can be made either by comparing the corresponding value of $\hat{R}(T)$ calculated for different rules, or by an estimation of the stability of this advantage in time, i.e. the length of interval T_s, so that for all t, $T_s \leq t \leq T$ in the given rule, $\hat{R}(t)$ exceeds the corresponding values for the market portfolio.
The realisation of these procedures of performance evaluation is rather time-consuming and has required the elaboration of a special software package "Monitoring of the Market" which provides an information database and a successive elaboration of portfolio structure.

C1. Usage of evolution series for decision-making in the GKO market in 1996

As was mentioned in the Introduction, the GKO market played a dominant role in 1996 and was the most attractive field for investment. The only problem was the choice between investments in different issues. Hence, during this period it was reasonable to take as a possible set of variants only the distribution of capital between the existing GKO issues on the market, the number of which did not exceed 12.
The method of Evolution Series, described above, allows the application of a statistical-optimisational approach to the elaboration of decision rules concerning this problem.
As the variables we took the values x_i, $i = 1,\ldots,12$, defining the shares of capital invested in the issue which corresponds to the evolution series with the same number (a larger number relates to issues closer to maturity). The uniqueness of the correspondence between an evolution series and the evolution intervals of specific issues allows us to find by the optimal values of x_i the volume of investments into these issues.
The «self-sufficiency» of the GKO market in the period under consideration allows a choice as forecasting factors only the histories of returns and the YTM. Of the variety of forecasting schemes considered above, we decided to analyse only two; namely, the Gauss predictor, i.e. a classical AR model; and the NNM predictor (the non-linear non-parametric rule of «nearest neighbours»).

Optimisation problems were solved for different values of parameter λ, characterising the risk aversion.
Summary data on the efficiency of different decision-making schemes are shown in Table 10 and illustrated by Figures 8 and 9.

Table 10. Characteristics of various decision-making algorithms.

Predictor	Window length	λ	R_p ,%	T_S
GAUSS	50	0.1	44.2	13
GAUSS	50	1	43.9	13
GAUSS	50	10	61.2	12
GAUSS	50	100	34.2	-
NNM (20)	100	0.1	56.2	102
NNM (20)	100	1	60.8	1
NNM (20)	100	10	53.1	101
NNM (20)	100	100	34.8	-

Market yield 36.3%

Figure 8. Final portfolio yield as a function of risk aversion parameter.

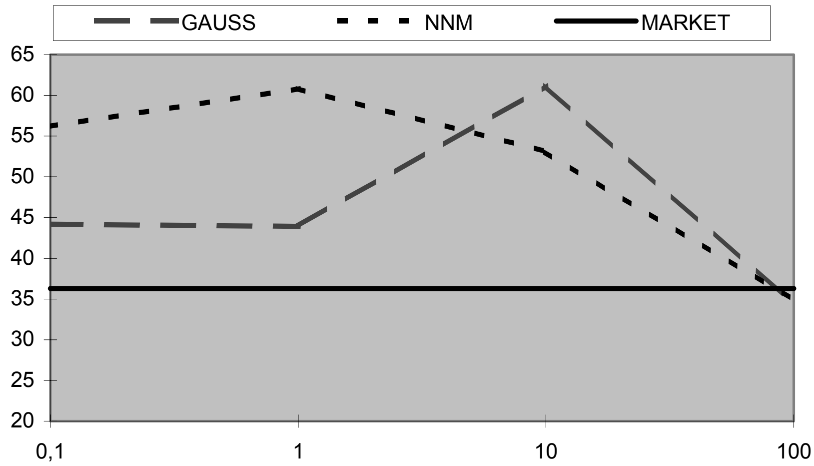
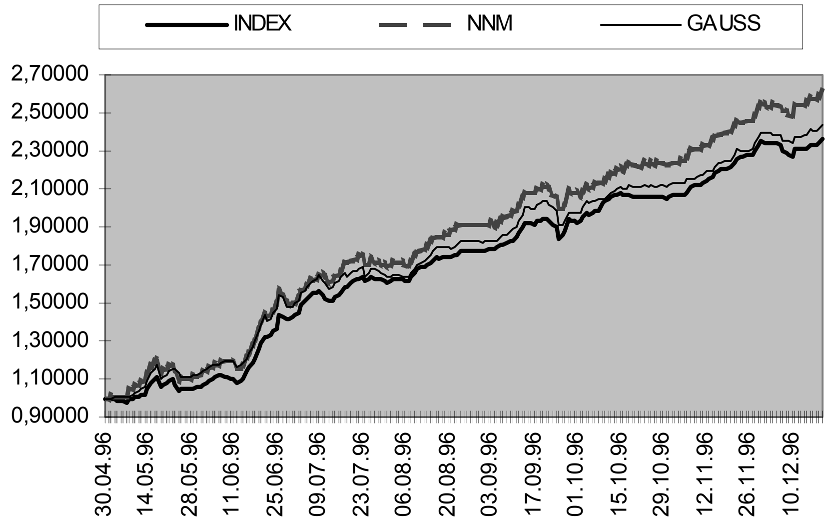


Figure 9. Evolution of portfolio returns and market index during the period 30.04.97 to 20.12.96.



The main conclusions are as follows:

- the suggested decision rules allowed the organisation of a GKO portfolio with an efficiency of up to 60%, which essentially exceeded the average market yield;
- the efficiency turned out to be sensitive to the choice of risk aversion in a non-monotone way,
- for $\lambda \leq 1$, the non-linear NNM predictor provided higher levels of efficiency.

Information concerning the evolution of the portfolio structure for different rules is too large. Note only that the optimal portfolio, as a rule, was weakly diversified and issues far from maturity usually were not included.

C2. Portfolio management in aggregate form (1996-1997)

From the end of 1996, the number of GKO issues existing simultaneously on the market strongly increased. On the other hand, the difference in returns between issues with nearly the same time to maturity became very small. Therefore, it seems sensible to elaborate the decision rules for that period only

in an aggregate form, when the investor is recommended to distribute capital between groups of issues which are essentially different in their time to maturity.
Efficiency was estimated based on the indices characterising each group. The following designations of aggregate variables were used:

x_1 - investment in GKO with a time to maturity from 1 to 30 days
x_2 - the same, but with a time to maturity from 1 to 3 months
x_3 - the same, but with a time to maturity greater than 3 months
x_4 - investment in currency (USD).

Investment returns are denoted correspondingly as RET1, RET31, RET91 and USDRET.
This section presents the results of the monitoring of aggregate decision rules in a relatively quiet period of market development. Two periods referring to the second halves of 1996 and 1997 were chosen for comparison.

Table 11. Statistics of portfolio components in the 2nd half of 1996.

	RET1	RET31	RET91	USDRET
$\mu*10^3$	1.26	1.83	2.80	0.45
$\sigma*10^3$	2.35	4.13	6.86	0.82

Table 12. Statistics of portfolio components in the 2nd half of 1997.

	RET1	RET31	RET91	USDRET
$\mu*10^4$	4.87	4.77	3.19	2.02
$\sigma*10^3$	0.45	1.00	2.43	1.25

During qualitative analysis of the factors affecting market behaviour, it was shown that, at that time, one could no longer speak of an absolute domination of the GKO market. The financial market was diversified and one could suppose an interrelationship between the various market sectors.

In view of the great variety of possible variants, the results of preliminary research were used to select variants for comparison:

- selection of the most important financial-economic factors in order to include them in information vector y_t;
- estimation of the degree of mutual correlation of the factors and their correlation with forecasted output R_{t+1}.

The original set of factors included:

- the history of portfolio components returns, $r_{i,\tau}$, $\text{i} = 1,..,4$
- the history of YTM and secondary trades volumes $Y_{i,\tau}, V_{i,\tau}$, $\text{i} = 1,..,3$
- the history of the Dow-Jones index DJ_τ and the corporate stock index of the Russian trade system (RTS) RTS_τ, as well as its increment $efRTS_\tau$.

According to the results of correlation and factor analysis for each period and each forecasted variable, the most significant factors were selected.
Finally, vectors y were formed as follows:

Table 13. Determining factors for various portfolio components.

Forecasted variable	Factors 1996	Factors 1997
$r_{1,t}$	$r_{1,t-7}, r_{4,t-7}$	$r_{1,t-7}, Y_{1,t-1}, RTS_{t-1}$
$r_{2,t}$	$r_{2,t-1}$	$r_{2,t-1}$
$r_{3,t}$	$r_{3,t-1}$	$r_{3,t-1}, r_{4,t-2}, \Delta RTS_{t-1}$
$r_{4,t}$	$r_{4,t-1}, Y_{1,t-1}, Y_{1,t-2}$	$r_{4,t-2}, Y_{1,t-1}$

One should mention the change in the structure of the basic factors over time. In 1997, the influence of the corporate stock market became apparent. As for the influence of the external market indicators mentioned above, it was essential only during a short period of time. Systematically, that influence was expressed only indirectly through internal market factors.
From the variety of forecasting algorithms, only the following types were considered:

a) AR model with an estimation by LSM (predictor "Gauss")
b) AR model with an estimation by LMM (predictor " Laplace")
c) Non-parametric rule of "nearest neighbours" (predictor NNM).

The first predictor was considered as a basic one for comparison. The two others were selected due to their advantages in forecasting accuracy shown during the preliminary tests (see above).

The following tables give some idea concerning the comparative empirical estimation results (annual returns are given in brackets; portfolio returns in dollars are denoted by $R_{p,\ USD}$).

Table 14. Results of the application of decision rules in the 2nd half of 1996. Market return in roubles, 34.0% (58.1). Market return in dollars, 19.4% (31.9).

Predictor	t_e	λ	R_p, %	$R_{p,\ USD}$	T_S
GAUSS	80	0.1	81.6 (154.3)	61.8 (112.2)	1
GAUSS	80	1	74.6 (139.1)	55.6 (99.6)	1
GAUSS	80	10	73.3 (136.3)	54.4 (97.3)	1
LAPLACE	100	0.1	83.6 (158.6)	63.6 (115.9)	1
LAPLACE	100	1	82.8 (156.9)	62.9 (114.5)	1
LAPLACE	100	10	77.5 (145.3)	58.1 (104.8)	1
NNM	130	0.1	80.8 (152.5)	61.1 (110.8)	1
NNM	130	1	80.6 (152.0)	60.9 (110.41)	1
NNM	130	10	80.7 (152.3)	61.0 (110.6)	1

Table 15. Results of the application of decision rules in the 2nd half of 1997. Market return in roubles, 6.3% (13.5). Market return in dollars, 3.2% (6.7).

Predictor	t_e	λ	R_p, %	R_p, %%	T_S
GAUSS	80	0.1	13.6 (30.3)	10.3 (22.5)	16
GAUSS	80	1	13.6 (30.3)	10.3 (22.5)	16
GAUSS	80	10	13.4 (29.8)	10.0 (22.0)	15
LAPLACE	80	0.1	14.0 (31.2)	10.7 (23.4)	7
LAPLACE	80	1	14.0 (31.2)	10.7 (23.4)	7
LAPLACE	80	10	14.0 (31.2)	10.7 (23.4)	7
NNM	150	0.1	11.1 (24.4)	7.9 (17.0)	5
NNM	150	1	11.0 (24.2)	7.8 (16.7)	5
NNM	150	10	10.9 (23.9)	7.7 (16.5)	5

Figures 10 and 11 give examples of graphs depicting the evolution of portfolio returns and the market index over time.

Figure 10. Evolution of portfolio returns and the market index in the second half of 1996.

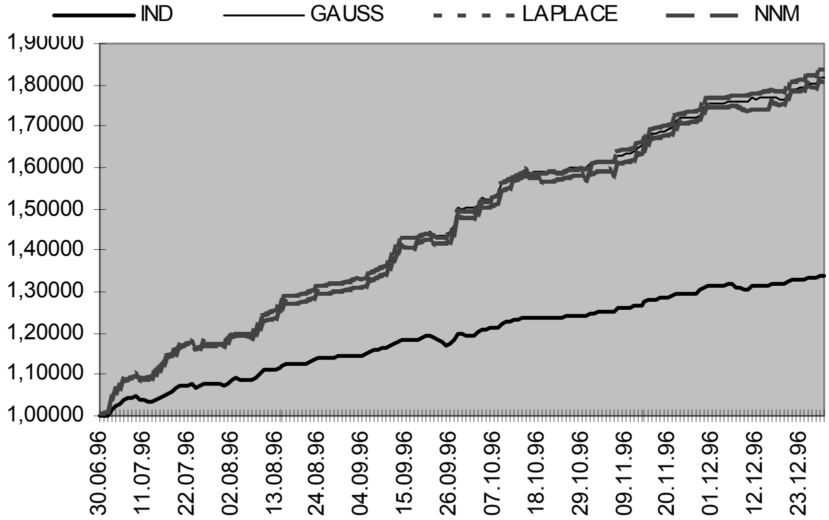
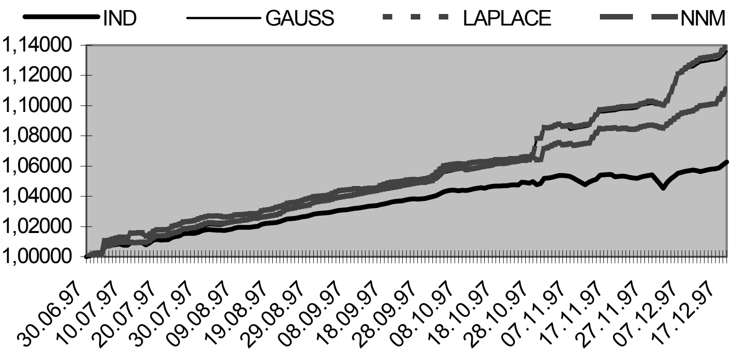


Figure 11. Evolution of portfolio returns and the market index in the second half of 1997.



Figures 12 and 13 illustrate the return as a function of the parameters of risk aversion. In all the calculations, decision rules based on the lowest aversion to risk gave the best results. Moreover, this effect was especially significant with the best predictors.

Figure 12. Yield as a function of the parameters of risk aversion for the second half of 1996.

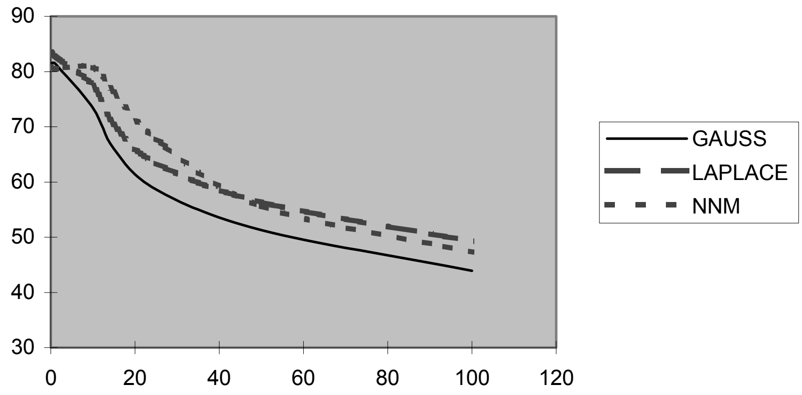
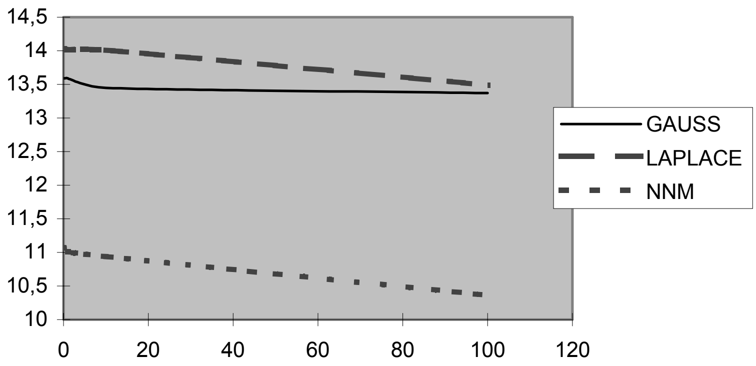


Figure 13. Yield as a function of the parameters of risk aversion for the second half of 1997.



We can now put forward some qualitative conclusions:

- the application of decision rules based on the use of statistical predictors and the optimal portfolio theory allowed investors to «beat» the market systematically;
- decision rules based on non-linear predictors have some advantages, although the gain in yield is less essential than the gain in forecasting accuracy;
- the higher the forecasting reliability, the more effective are the rules at higher levels of risk;
- a non-diversified portfolio using only one asset forecast as the best one under the "nearest neighbours" scheme, i.e. the most risky optimal portfolio, gave good results in both the periods analysed.

The last conclusion confirms the judgment expressed above that there is no absolute contradiction between the recommendations of classical technical analysis, based on the study of similar current situations in the market to the situations observed earlier, and the recommendations of the optimal portfolio theory. Of course, this refers to the modified theory which uses forecasting and the general concept of technical analysis provided by non-parametric statistical methods.

Of course, the authors can not insist on the correctness of this conclusion outside of the empirical material. Moreover, the analysis in the period of instability presented below demonstrates the advantages of more cautious tactics.

It is necessary also to have in view that, in our comparison of various decision rules, transaction costs were not taken into account. However, they play an essential role, even if the structure of investment portfolios remain unchanged. Besides, the absence of diversification is understood above in the aggregate sense and does not exclude diversification within each group of assets.

C3. Decision Rules During Periods Of Instability (1998)

During data analysis relating to the last period of the operation of the GKO market, the same methods were used as in the previous section. Sampling for the period 01.09.97-01.08.98 was undertaken and the same factors were considered as in the 2^{nd} half of 1997. The data set of histories for each component comprised 335 points. Portfolio management started after a 40 point trial period.

Statistics of the means and standard deviations for one-day returns is given in Table 16 for the different components.

Table 16. Portfolio components statistics.

	RET1	RET31	RET91	USDRET
$\mu*10^4$	8.24	7.74	5.72	2.76
$\sigma*10^3$	2.61	8.22	13.9	2.26

It is obvious that volatility essentially increased in comparison to 1997 for all the components, while short-term issues (RET1) were dominant.
The results of monitoring the application of optimal decision rules based on the Gauss predictor are given in Table 17 for different values of the parameters of risk aversion.

Table 17. Final yield of portfolio management.

λ	Portfolio I	Portfolio II	Portfolio III
0.1	39.84	53.1	52.8
1	39.71	53.07	54.73
10	49.45	57.28	56.7
100	46.13	52.21	52.1

Column I presents the final yield in % during the period of portfolio management (292 days) excluding currency operations. The forecast also used only GKO market data. Column II presents the yield of the same portfolio but with the forecast taking into account the change in the exchange rate and the Dow-Jones index. In the last column, the forecast remained the same but the portfolio included investment in currency also.
The market yield during that period was equal to 24%.
It is important to note that:

- even the simplest predictor allows investors to «beat» the market;
- the systematic consideration of external factors has a strong impact, improving forecasting quality and, consequently, the return;
- the influence of risk aversion is non-monotone and not particularly strong;
- the possibility of including currency in the portfolio did not produce a positive effect.

An analysis of the change in portfolio structure shows that the number of days when it was recommended that currency be included in the portfolio was 8-13% of the entire managed period.

More detailed information concerning the evolution of portfolio structure is given in Appendix B. Here one should note that, as a rule, the optimal portfolio appeared to be non-diversified and that investments in short-term GKO issues were recommended. Table 18 presents data on the number of days when a diversification in Portfolio III took place.

Table 18. Number of days of portfolio diversification.

λ	0.1	1	10	100
Number of days	0	0	13	72

It is clear that diversification took place only within more «cautious» assessments. Capital transfer into currency was recommended only during the period 14-22 July, after it was announced that the issuing of further short-term bonds was being stopped.

Some qualitative remarks are illustrative.

Firstly, the application of optimal decision rules for short-term operations on the GKO market facilitated the achievement of a high yield even during the period of an unstable market. Secondly, in that period a special role was played by external factors, such as the state of the currency market and the position of the international capital markets.

It is natural that forecasting quality and, consequently, the efficiency of the process could be improved if the influence of the international market was taken into account in a more detailed way. First of all, it implies considering the behaviour of other «emerging» markets and not only the Dow-Jones index. Unfortunately, the authors did not establish a corresponding database. At the same time, one should emphasise that a purely statistical approach, which does not take into account the role of fundamental factors (the state of and forecasts for the budget deficit and the external accounts deficit) is not able in principle to forecast the collapse of the market, such as happened in the middle of August 1998. The application of other formal forecasting schemes (e.g., NNM) also did not take effect in view of the short length of sampling in such non-stationary conditions.

5. CONCLUSIONS AND RECOMMENDATIONS

In conclusion, we present the summary of the fundamental results obtained during the work on the project and give some qualitative conclusions and recommendations for further research.

1. The qualitative analysis of the basic stages of the history of the Russian state bond market was conducted and the major factors relevant for forecasting were specified.
2. The peculiarities of debt policy were described and the dominant influence of competition with the currency market in its realisation was shown.
3. The hypothesis was made that the rejection of the printing of money and the inflationary regulation of imports under a strong fall in export prices, as well as the internationalisation of internal debt, became the basic reasons for the currency market crisis which provoked the crash of the GKO system.
4. Analysis of some medium-term forecasting schemes was carried out and the role of issuing policy was specified, along with the socio-political factors leading to the temporary destabilisation of the market.
5. A scheme of evolution series was suggested, which allowed a consideration of the returns of short-term operations in the GKO market as stochastic sequences, and statistical data describing specific features of these sequences (non-stationarity, non-Gaussianness, presence of autocorrelation) were obtained.
6. The facility of returns forecasting by means of various statistical algorithms was investigated and the better adequacy of non-linear algorithms, and non-parametric statistical methods in particular, was proved.
7. For short-term speculation, some formal decision rules were suggested using forecasting algorithms and the modified theory of an optimal portfolio of risky securities.
8. It was found out that speculation in the GKO and currency markets provided the achievement of an extremely high level of returns (more than 100% per annum in the 2nd half of 1996 if calculated in US dollars), which more than doubled the return on the yield to maturity index.
9. Estimates of the expected returns of various GKO issues and their volatility were obtained, and it was shown that these differed strongly for various periods characterised by different state debt policy.

10. The systematic monitoring of the application of decision rules was carried out based on real empirical data with a performance evaluation for different periods.
11. It was shown that the class of efficient decision rules under consideration can be interpreted as the formalised generalisation of the recommendations of classical technical analysis.
12. It was demonstrated that efficient forecasting and decision-making in the GKO market since 1997 was impossible if its interaction with other sectors, both the internal financial market and the world market, was not taken into account.

All the results given above have been proved by detailed statistical analysis, using a database of the GKO market and the currency market, as well as the credit market, the Russian corporate stock market and the Dow-Jones index as a basic indicator of the state of the world market. Data on the volume of state bonds in issue and the state budget deficit were also used.

We should emphasise that the project was directed only to research into medium-term and short-term market fluctuations and an analysis of the efficiency of short-term speculative investments. As for the problems connected with an analysis of the general reasons for the instability of the GKO market which led to its collapse, they were considered only in a qualitative fashion. Undoubtedly, there is still a very acute problem concerning the quantitative modelling of the processes of the development of instability. This needs to be made on the basis of a more profound study not only of the Russian market but of similar processes in other markets in developing countries.

The short life of the state debt system in Russia does not assist the making of firm recommendations concerning the policy of its recovery and future evolution. However, the authors of the project can suggest the following statements as hypotheses yielding from the analysis.

- state debt policy can not be considered separately from other schemes of budget deficit financing, primarily the printing of money and the regulation of external accounts, and consequently an inflexible state debt policy is doomed to failure
- an export structure based on raw materials can not be changed in the next 5-10 years, and thus the strong dependence of currency inflow on world price levels can not be overcome, which leads to the necessity of a policy regulating imports

- in conditions of an open market economy, imports can be regulated only by the regulation of the exchange rate through the money supply
- it is reasonable to diminish the speculative character of the internal debt market, substituting discount-type bonds by per cent securities with a flowing interest rate tied to the exchange rate.

REFERENCES

Bak, P., *How Nature Works: The Science of Self-Organised Criticality*. Copernicus/Springer, Berlin, 1996.

Barinov V., Pervozvanski A. and Pervozvanskaja T., «Forecasting in the Short-Term Bond Market», *Vestnik S.-Peterburgskogo Universiteta*, (*S. Petersburg University Bulletin*), ser. «Economics», 1997, No. 1.

Bollerslev T.P., «Generalised Autoregressive Conditional Heteroscedasticity», *Jour. Econometrics*, 31, 1986, pp. 307-327.

Broeker G., *Government Securities and Debt Management in the 1990s*, OECD, Paris, 1993.

Butsev A. and Pervozvanski A., *Local Approximation on Artificial Neuronets*. //AT.1995. No 9. pp.127-136.

Engle, Robert F., «Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of UK Inflation», *Econometrica*, 1982, 50, pp. 987-1007.

Engle, Robert F., Lilien, David M. and Robins, Russell P., 1987, «Estimating Time-Varying Risk Premia in the Term Structure: The ARCH-M Model», *Econometrica*, 55, pp. 391-407.

Engle, Robert F. and Victor K. Ng, «Measuring and Testing the Impact of News on Volatility», *Journal of Finance*, 1993, 48/5, pp. 1749-1778.

Fabozzi F.J., *Bond Markets, Analysis and Strategies*, Prentice-Hall, N.J., 1996 (3rd ed.), pp.1-595.

Fabozzi F.J., Modigliani, F. and Ferri, G., *Foundations of Financial Markets and Institutions*, Prentice-Hall, N.J., 1994, pp. 1-666.

GKO: Theory and Practice of the Market, Article Coll. , M., MMVB, 1995.

Gourieroux, C., *ARCH Models and Financial Applications*, Springer V., N.Y., 1997.

Grinold, R.C. and Kahn, R.N., *Active Portfolio Management*, Probus P. Co., Chi., Ill., Cambr., UK, 1995.

Gryadovaya O., «The Features of Pricing in the GKO Market», *Financi* (*Finance*) Journal, 1995, No. 3, pp. 21-25.

Gryadovaya O., «Pricing in the GKO Market», *Russian Journal of Economics*, 1995, No.4, pp.45-54.

Guberniev V., «GKO in the Optimal Portfolio», *Rynok tsennych bumag* (*Assets Market*) ¹15, 1996, pp.6-8.

Haliasses M. and Tobin J., «The Macroeconomics of Government Finances», in *Handbook of Monetary Economics*, v.2., North-Holl., Amst., 1990.

Hicks, J.R., *Value and Capital*, Oxford Univ. Press, L., 1946.

Kariya T., *Quantitative Methods for Portfolio Analysis*, Kluwer Acad. Publ., 1993.

Katkovnik V. *Nonparametric Identification and Smoothing of Data: Local Approximation Method*. M.:Nauka, 1985.

Ljung G. and Box G., «On a Measure of Lack of Fit in Time Series Models», *Biometrika*, 1979, 66, pp. 265-270.

Lutz, F.A., «The Structure of Interest Rates», *Q. Journ. Econ*., 1940, Nov., pp.36-63.

Modigliani, F. and Sutch, R., «Innovations in Interest Rate Policy», *Am. Econ. Rev*., 1966, May, pp.178-197.

Nelson, Daniel B., «Conditional Heteroscedasticity in Asset Returns: A New Approach», *Econometrica*, 1991, 59/2, pp. 347-370.

Pervozvanski A., Barinov V., «Forecasting and Optimisation in the Short-Term Bond Market», *Ekonomika i Matematicheskie Metodi* (*Economics and Mathematical Methods*), 1997, No.4.

Pervozvanski A., «Inflation is Better than Depression», *Sankt-Peterburgskie vedomosti*, 22.11.1996, p.4.

Pervozvanski A., «An Optimal Portfolio for a Non-Stationary Security Market», *Transition-97*, Warsaw, 1997, p.328-331.

Pervozvanski A., «On the Mutual Relations between the Rate of Inflation and Exchange Rate», *Ekonomika i Matematicheskie Metodi* (*Economics and Mathematical Methods*), 1998, No.1, pp.173-176.

Pervozvanski A. and Pervozvanskaja T., *Financial Market*, M., Infra-M, 1993.

Pervozvanski A., Pervozvanskaja T. and Barinov V., «Forecasting in the Short-Term Bond Market», *Vestnik SPbU*, ser."Economics", 1997, No. 1.

Sharpe, W.F. and Alexander, G.J., *Investments*, Prentice-Hall, 1990.

Sinkey, J.F. *Commercial Bank Financial Management*, McMillan P. Co., N.Y., 1992.

Sundararajan V., Dattels P. and Blommstein, H., *Co-ordinating Public Debt and Monetary Management*, IMF, Wash.D.C., 1997.

Taylor S.J., *Modelling Financial Time Series*, J.Wiley, N.-Y., 1986.

Zenious S.A. (ed.), *Financial Optimisation*, Camb.Uni.Press, 1995.

APPENDICES

A. Data on mean-term forecasting of the GKO yield index

Table A1. Basic data.

Date	Index (t)	b/M2(t-1)	Credit rate (t-1)	Dollar rate (t-1)
Feb.96	0.047	0.014	0.171	0.023
Mar.96	0.091	0.042	0.154	0.018
Apr.96	0.090	0.087	0.148	0.007
May.96	0.132	0.070	0.150	0.019
Jun.96	0.095	0.072	0.146	0.013
Jul.96	0.062	0.059	0.150	0.013
Aug.96	0.059	0.045	0.125	0.023
Sep.96	0.049	0.067	0.104	0.030
Oct.96	0.044	0.037	0.129	0.006
Nov.96	0.035	0.055	0.079	0.009
Dec.96	0.030	0.047	0.075	0.009
Jan.97	0.026	0.034	0.058	0.010
Feb.97	0.023	0.032	0.063	0.012
Mar.97	0.028	0.054	0.053	0.009
Apr.97	0.026	0.049	0.050	0.009
May.97	0.022	0.022	0.042	0.007
Jun.97	0.015	0.030	0.046	0.002
Jul.97	0.015	0.050	0.042	0.001

Table A2. Correlation of index and regression factors.

	Index	b/M2(t-1)	Credit rate (t-1)	Dollar rate (t-1)	Index (t-1)
Index	1				
b/M2 (t-1)	0.59507	1			
Credit rate (t-1)	0.81178	0.30976	1		
Dollar rate (t-1)	0.43432	0.07573	0.56046	1	
Index (t-1)	0.81951	0.64196	0.78524	0.36588	1

B. Database and construction of the evolution series

The database used includes the initial information on GKO trades for the period 01.01.95 - 31.10.97 (total size exceeds 2MB). All GKO issues were put in time-to-maturity descending order for each date, and evolutionary series were extracted. As an example, the sample for 01.06.96 - 01.08.96 is shown below, including two evolutionary series only. The columns of the table relate to the following variables:

DATE:	Date of trades
IdXX:	Issue ID*
CXX:	Closing price**
ECXX:	Evolutionary series element***

DATE	ID01	C01	EC01	ID02	C02	EC02
1996-06-01	0005Z	52.783	0.005397	0005W	55.383	0.017141
1996-06-02	0005Z	53.067	0.005368	0005W	56.317	0.016852
1996-06-03	0005Z	53.35	0.005339	0005W	57.25	0.016573
1996-06-04	0005Z	54.55	0.022493	0005W	57.0	-0.004367
1996-06-05	00061	53.13	0.0	0005Z	54.775	0.004125
1996-06-06	00061	53.05	-0.001506	0005Z	55.0	0.004108
1996-06-07	00061	52.51	-0.010179	0005Z	53.6	-0.025455
1996-06-08	00061	52.307	-0.003872	0005Z	53.5	-0.001866
1996-06-09	00061	52.103	-0.003887	0005Z	53.4	-0.001869
1996-06-10	00061	51.9	-0.003903	0005Z	53.3	-0.001873
1996-06-11	00061	49.5	-0.046243	0005Z	50.57	-0.05122
1996-06-12	00061	50.527	0.020741	0005Z	51.897	0.026234
1996-06-13	00067	44.46	0.0	00061	51.553	0.020319
1996-06-14	00067	51.97	0.168916	00061	52.58	0.019915
1996-06-15	00067	53.48	0.029055	00061	53.903	0.025168
1996-06-16	00067	54.99	0.028235	00061	55.227	0.02455
1996-06-17	00067	56.5	0.02746	00061	56.55	0.023962
1996-06-18	00067	59.05	0.045133	00061	59.95	0.060124
1996-06-19	00068	59.59	0.0	00067	60.775	0.029213

* ID01 corresponds to the issue with the longest period to maturity, ID02 corresponds to the issue following ID01 according to the period to maturity, etc.
** CXX - closing price
*** ECXX - daily return of GKO issue

1996-06-20	00068	61.7	0.035409	00067	62.5	0.028383
1996-06-21	00068	60.55	-0.018639	00067	62.0	-0.008
1996-06-22	00068	61.563	0.016735	00067	63.05	0.016935
1996-06-23	00068	62.577	0.01646	00067	64.1	0.016653
1996-06-24	00068	63.59	0.016193	00067	65.15	0.016381
1996-06-25	00068	67.9	0.067778	00067	69.49	0.066616
1996-06-26	00069	66.76	0.0	00068	67.2	-0.010309
1996-06-27	00069	64.7	-0.030857	00068	66.5	-0.010417
1996-06-28	00069	64.4	-0.004637	00068	66.4	-0.001504
1996-06-29	00069	65.167	0.011905	00068	67.0	0.009036
1996-06-30	00069	65.933	0.011765	00068	67.6	0.008955
1996-07-01	00069	66.7	0.011628	00068	68.2	0.008876
1996-07-02	00069	68.57	0.028036	00068	71.0	0.041056
1996-07-03	00069	69.347	0.011327	00068	71.75	0.010563
1996-07-04	0006A	68.24	0.0	00069	70.123	0.0112
1996-07-05	0006A	69.35	0.016266	00069	70.9	0.011076
1996-07-06	0006A	69.667	0.004566	00069	71.25	0.004937
1996-07-07	0006A	69.983	0.004545	00069	71.6	0.004912
1996-07-08	0006A	70.3	0.004525	00069	71.95	0.004888
1996-07-09	0006A	69.0	-0.018492	00069	70.0	-0.027102
1996-07-10	0006F	66.23	0.0	0006A	68.08	-0.013333
1996-07-11	0006F	65.04	-0.017968	0006A	67.16	-0.013514
1996-07-12	0006F	65.6	0.00861	0006A	67.03	-0.001936
1996-07-13	0006F	66.193	0.009045	0006A	67.727	0.010393
1996-07-14	0006F	66.787	0.008964	0006A	68.423	0.010286
1996-07-15	0006F	67.38	0.008884	0006A	69.12	0.010182
1996-07-16	0006F	69.35	0.029237	0006A	70.77	0.023872
1996-07-17	0006F	69.33	-0.000288	0006A	70.89	0.001696
1996-07-18	0006F	69.02	-0.004471	0006A	70.6	-0.004091
1996-07-19	0006F	69.99	0.014054	0006A	71.21	0.00864
1996-07-20	0006F	70.393	0.005763	0006A	71.807	0.008379
1996-07-21	0006F	70.797	0.00573	0006A	72.403	0.008309
1996-07-22	0006F	71.2	0.005697	0006A	73.0	0.008241
1996-07-23	0006F	69.01	-0.030758	0006A	71.54	-0.02
1996-07-24	0006F	69.895	0.012824	0006A	72.02	0.00671
1996-07-25	0006F	70.78	0.012662	0006A	72.5	0.006665
1996-07-26	0006F	70.15	-0.008901	0006A	72.15	-0.004828
1996-07-27	0006F	69.727	-0.006035	0006A	71.67	-0.006653
1996-07-28	0006F	69.303	-0.006071	0006A	71.19	-0.006697
1996-07-29	0006F	68.88	-0.006108	0006A	70.71	-0.006743
1996-07-30	0006F	68.55	-0.004791	0006A	70.38	-0.004667
1996-07-31	0006R	65.15	0.0	0006F	68.44	-0.001605
1996-08-01	0006R	65.42	0.004144	0006F	68.33	-0.001607

C. Results of statistical tests on the evolution series

Table C1. Normality tests for evolutionary series (Sample size 238: 1 to 238).

Evolutionary Series	ES01	ES02	ES03	ES04	ES05	ES06
Mean	0.00371	0.00337	0.00333	0.003358	0.00328	0.00369
Std.Devn.	0.01942	0.01480	0.01384	0.01338	0.01346	0.01134
Skewness	2.61446	-0.08364	-0.52282	0.26595	-0.41456	0.48625
Excess Kurtosis	23.61703	4.56026	6.74879	5.99901	9.54993	6.93394
Minimum	-0.07571	-0.05122	-0.07763	-0.05564	-0.07704	-0.05417
Maximum	0.16892	0.06662	0.05038	0.07463	0.06584	0.05887
Normality Chi^2(2)	141.65**	102.26**	147.81**	142.09**	248.93**	156.92**

Table C2. Non-stationarity tests:

a) F-Test Two-Sample for Variances

	ES01		ES02		ES03	
	1-119	120-238	1-119	120-238	1-119	120-238
Mean	0.0039996	0.0034225	0.002939	0.003791	0.003092	0.00357
Variance	0.0006781	8.239E-05	0.000367	7.41E-05	0.000315	7.17E-05
Observations	119	119	119	119	119	119
df	118	118	118	118	118	118
F	8.2306421		4.953236		4.386381	
P(F<=f) one-tail	2.007E-26		6.86E-17		7.46E-15	
F Critical one-tail	1.3553585		1.355358		1.355358	
df	146		164		169	
t Stat	0.2282777		-0.44256		-0.26524	
P(T<=t) one-tail	0.4098749		0.329334		0.395575	
t Critical one-tail	1.6553577		1.654198		1.653921	
P(T<=t) two-tail	0.8197498		0.658669		0.79115	
t Critical two-tail	1.9763456		1.974536		1.974099	

b) t-Test: Two-Sample Assuming Unequal Variances

	ES04		ES05		ES06	
	1-119	120-238	1-119	120-238	1-119	120-238
Mean	0.003588	0.003573	0.00326	0.003296	0.00409	0.003294
Variance	0.000307	5.45E-05	0.000313	5.27E-05	0.000216	4.32E-05
Observations	119	119	119	119	119	119
df	118	118	118	118	118	118
F	5.626739		5.935827		4.999528	
P(F<=f) one-tail	3.89E-19		4.13E-20		4.75E-17	
F Critical one-tail	1.355358		1.355358		1.355358	
df	159		157		163	
t Stat	0.008204		-0.02055		0.539594	
P(T<=t) one-tail	0.496732		0.491815		0.295107	
t Critical one-tail	1.654494		1.654616		1.654255	
P(T<=t) two-tail	0.993464		0.98363		0.590213	
t Critical two-tail	1.974995		1.975191		1.974622	